HEALTH CARE NETWORK COMMUNICATIONS INFRASTRUCTURE: AN ENGINEERING DESIGN FOR THE MILITARY HEALTH SERVICE SYSTEM

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ABSTRACT

The Military Health Service System (MHSS) provides health care for the Department of Defense (DOD). This system operates on an annual budget of $15 Billion, supports 127 medical treatment facilities (MTFs) and 500 clinics, and provides support to 8.7 million beneficiaries worldwide. To support these facilities and their patients, the MHSS uses more than 125 different networked automated medical systems. These systems rely on a heterogeneous telecommunications infrastructure for data communications. With the support of the Defense Medical Information Management (DMIM) Program Office, our goal was to identify the network requirements for DMIM migration and target systems and design a communications infrastructure to support all systems with an integrated network. This work used tools from Business Process Reengineering (BPR) and applied it to communications infrastructure design for the first time. The methodology and results are applicable to any health care enterprise, military or civilian.

BACKGROUND

Strategically, the goal of this engineering project is to design a comprehensive and scaleable telecommunications infrastructure. This infrastructure will support an integrated array of migration and target automated medical systems from a building, campus, and wide area perspective. Although a DOD organization, the MHSS is a large health maintenance organization with an unique national readiness mission. This project focused on medical information systems that comprise the MHSS computer network infrastructure.

For the most part, MHSS systems rely on their individual network infrastructures. This causes us to be in a perpetual facility cabling situation, requires multiple maintenance and support agreements, and results in redundancies of physical cable pathways and communications gear at the facility level. Further, this mix of stand-alone architectures prevents a coherent, proactive network management framework in line with government directives and standards [1]. The foundation of the engineering effort is the analysis of all internal telecommunications systems interfaces, to include the identification of long haul requirements, such as telemedicine. A set of 14 MHSS Air Force, Army, and Navy facilities, ranging from teaching medical centers to outpatient clinics, geographically located throughout the continental United States provided the sample for this program.

The 125 MHSS automated systems support common areas such as medical records, outpatient scheduling, ancillary clinical support, point of care, readiness, administration, and other areas found throughout its medical treatment facilities. Of the 125 systems, 41 migration or target systems required engineering as they represented the entire functionality of all MHSS systems. We viewed the systems as stand alone first, then in an integrated model with inter- and intra-facility views, to form an enterprise model. These 41 systems also served as the traffic analysis and bandwidth demand targets for the design. For the first time, we used tools from Business Process Reengineering (BPR) and computer aided manufacturing to develop a comprehensive communications architecture. To represent the systems on an enterprise basis, we chose to use Integrated Computer-Aided Manufacturing DEFinition (IDEF) at a high level. From BPR, we used As-Is templates for the MHSS existing

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telecommunications infrastructure and To-Be designs supported by the IDEF that will build the enterprise in an integrated fashion.

On October 1, 1994, the Medical Systems Infrastructure Modernization (MSIM) project began. The project consists of four major phases: Phase 1, IDEF development; Phase II, MHSS Enterprise As-Is Templates; Phase III, Facility As-Is Templates; and Phase IV, Enterprise To-Be Design. This paper reports the results of Phases I and II. The methodology and results presented here support an integrated communication design effort applicable to any medical enterprise.

METHODOLOGY

Modeling -- Functional Approach
Architectures and functionality of automated systems used to support the many areas of a medical enterprise vary. Therefore, we decided to gain a high level functional (IDEF) view to serve as a baseline during development of the overall architecture design. IDEF, which uses structured analysis and design techniques, presents a model with a single subject, purpose, and viewpoint [2]. The IDEF tool allowed the team to rapidly determine the general requirements supported by each medical system. It also supports engineers during the telecommunications design phase. Development of a high-level model followed by definition and modeling of each selected medical system formed our baseline. Graphically depicting functionality supports the overall health care mission of the medical enterprise. Working with system users and guided by the various models, the team was able to identify the data communications demands of each system. For the first time, we saw an integrated foundation for an overall design. The specific steps we used in the process are:

- Determine scope, purpose, and viewpoint of the high level model
- Evaluate existing information and determine which systems to include
- Develop a set of questions that would be used on surveys
- Schedule interviews and start building the high level model
- Validate the accuracy of the model through peer and functional experts
- Model each of the systems identified in the high level model in detail

Modeling -- Physical Approach
Collection of physical communications characteristics (such as protocol stacks and transmission media) supported the development of individual system templates. We used a database to store all pertinent data, also providing support for Phase II. The physical approach addressed the design issues listed below:

- Physical wiring implementation
- Equipment that comprised the network
- Signaling
- Protocols
- Surge time periods
- Packet and Frame sizes
- Traffic patterns and characteristics

As-Is Models and Templates
The cverall success of the project is greatly dependent on Phases II and III. The product of these phases provides a snapshot of the 41 migration and target systems, the state of the infrastructure existent at each facility, and its ability to support the planned enterprise. The majority of existing networks support a single system. Some plans exist in support of multiple systems (i.e., DMIM's major clinical support system and the Composite Health Care System fiber backbone) but failed to address user and bandwidth demands. The site-unique, As-Is models serve as a template in the design of a comprehensive network infrastructure that maximizes the reuse of existing, standards-based components.

The MHSS Enterprise As-Is Template (Phase II) consists of the communications-computer analysis of each of the 41 migration and target systems from the DMIM program office. We made determinations regarding planned program implementations and long-haul demand issues for the entire MHSS enterprise during this phase.

The detailed survey of the 14 MTFs included collection of data required to support the overall technical assessment of each facility and completes Phase III. Simultaneously, we verified data gathered during the Enterprise Template build such as network loading, bandwidth demand, civil engineering requirements, current and future data communication equipment location, and cable routings at the sites. Additionally, we examined campus interfaces, long haul requirements, and any other unique systems that generated a data communications requirement.

To-Be Design Blueprints

By using data from Phases I through III, blueprint design (Phase IV) can begin. The previous phases identified the unique characteristics of each site and placed 41 DMIM migration and target systems into an integrated model using IDEF. An analogy from the architectural profession is useful. An architect first determines the requirement, analyzes the structural algorithms needed to support the requirements, then designs blueprints. Similarly, Phases I through III will identify and organize the requirements of the data set for the To-Be design. The tools we used were IDEF and BPR and the result is a blueprint for each facility. These blueprints (to be presented in a later publication) describe the architecture that represents a significantly improved infrastructure. The To-Be design must:

- Comply with existing standards and support anticipated future standards
- Support scalability
- Support modular design
- Be secure
- Be open and interoperable
- Identify support requirements
- Utilize existing infrastructure to the greatest extent possible
- Support technology insertion

RESULTS

Overview

We agree with reports from other groups that implementation costs for such a design are significant [3]. However, we believe the cost of continuing to build, maintain, and manage a non-integrated network, is unacceptable. We base this opinion on the growing requirement to (1) host critical health care systems; (2) support multi-protocol networks; and (3) find, train, and retain qualified network systems administrative personnel. Therefore, we chose to design to the entire facility and capitalize on existing infrastructure allowing future system implementations in a "plug and play" manner. We believe this will greatly reduce implementation time and associated costs. Our goal was to design the infrastructure within one year, test in a laboratory environment, and then start construction at (at least) one major medical center.

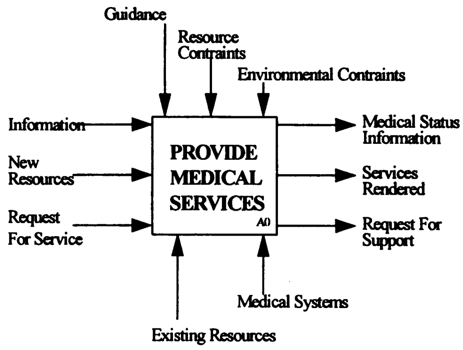

Figure 1. IDEF Functional Model.

Modeling

Figure 1, above, depicts the context diagram for the IDEF model describing activities associated with providing medical services at the medical treatment facility (MTF) level. The outside of the box depicts the Inputs, Constraints, Output and Mechanisms (ICOMs). Three primary inputs (entering at the left) required to PROVIDE MEDICAL SERVICES are Information, New Resources, and Request For Service. A Request For Service can be anything from an individual requesting a medical appointment to Regional Headquarters directives requiring a monthly report on some aspect of the MTF's operation. The constraints (shown at the top) on PROVIDE MEDICAL SERVICES are Guidance, Resource Constraints, and Environmental Constraints. The outputs (exiting to the right) are Medical Status Information, Services Rendered, and Request For Support. Medical Status Information may be a monthly report provided to the regional headquarters or a response to a query on the results of a laboratory specimen. Mechanisms to PROVIDE MEDICAL SERVICES (shown at the bottom) are Existing Resources and Medical Systems. Activities required to perform PROVIDE MEDICAL SERVICE are identified and modeled in a similar fashion to this overarching diagram.

Figure 2, next page, is a node tree illustrating the hierarchical relationships between the main activity and its constituent sub-activities. The

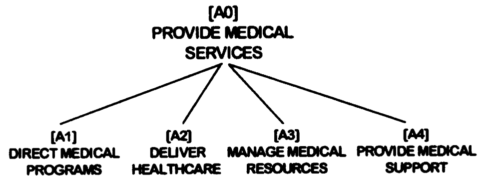

Figure 2. Node tree.

four sub-activities are: Direct Medical Programs, Deliver Health Care, Manage Medical Resources, and provide Medical Support Services.

The first step in engineering an enterprise communications architecture is to build the business logic behind the requirements needed to produce the bandwidth requirements followed by engineering the design. This ensures the architect that requirements layered into the IDEF model result in an integrated, justified, and logical communications design. Phase II began after completion of the IDEF model design and documentation. Data collection methodology consisted of on-site visits to both system program offices and sites with migration systems in operation. The study addressed requirements for functionality, network (used or planned), and other features of the system. We used the IDEF model to illustrate each singular system. A portion of the results from the Medical Diagnostic Imaging System (MDIS) follows. This system supports filmless (digitized) radiology services for the MHSS.

MDIS uses an advanced, high speed, fault-tolerant server, combined with 100 Mbps fiber data links, to move images from acquisition devices to imaging workstations. MDIS imaging workstations are personal computers enhanced with specialized processing and display hardware. A central host processor provides system control, database management, and security features. The system can be linked to geographically remote sites through a gateway on the Local Area Network and leased telephone circuits. The architecture divides into four logical subsystems: Communications and network, image database and storage, image acquisition, and image output and display subsystems.

Figure 3, below, depicts the MDIS communications protocol stack which is consistent with those protocols adopted by the MHSS [4]. Determining performance characteristics of various telecommunications media required a look at communications protocols; along with the actual physical media, theoretical throughput, and the overhead associated with protocol "encapsulation." These are key in responding to Quality of Service (QOS) issues, such as time of response. MDIS uses layer 1 Ethernet Carrier Sense Multiple Access and Collision Detection (CSMA/CD) for control messaging and Fiber Distribution Data Interface (FDDI) for distribution of images. The ethernet's 10 Mbs theoretical throughput is

	OPEN SYSTEM PROTOCOLS	MHSS		MDIS
Layer 1	PHYSICAL: Transparent transfer of data between systems. ISO 8072 documents and CCITT X.213	TCP		TCP
Layer 2	NETWORK: Routing and relaying data on the network or between networks. ISO 8348 and CCITT X.213	IP		IP
Layer 3	DATA LINK: Link established between directly connected systems ISO 8886	IEEE 802.2	X.25	IEEE 802.2
Layer 4	TRANSPORT: The exchange of data at the bit level through transmission media. CCITT X.211	IEEE 802.3		ANSI X.39 (FDDI) 100Mbps Fiber

Figure 3. MDIS open systems comparison.

more than sufficient for routine messaging [5]; however, it cannot efficiently transfer the large 5-7 MB files (diagnostic quality images) associated with MDIS. The theoretical 100 Mbps throughput capability of FDDI ensures a QOS response time of 5 seconds for image transmission and display. Figure 4, below, represents the MDIS high-level IDEF functional model.

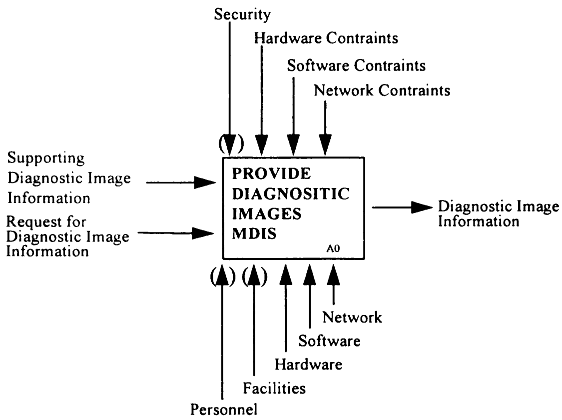

Figure 4. MDIS Functional Model

Non-deployed systems presented a different problem for the team. New, "migration," or "target" systems, required estimates using as detailed information as is available concerning data transfer requirements and system design. Collection of design data "categorized" all 41 target and migration systems using information obtained through actual measurement or use of traffic analysis techniques and resulted in the MHSS Enterprise As-Is Template. This template, when combined with facility unique data, will support the design of the network enterprise.

NEXT STEPS

The foundation is now in place to design a comprehensive and enduring health care data communications architecture to support the needs of the MHSS enterprise. This design, coupled with an acquisition strategy, postures the MHSS to begin streamlined and integrated installations for all of its medical automation systems.

CONCLUSION

The MHSS is a Health Maintenance Organization that is reliant upon a wide array of medical information systems for support. The need to design an integrated network to support its automated systems is paramount to continuing the MHSS's future in providing high quality health care while controlling costs. The critical need for a homogeneous communications architecture becomes inevitable as demands on the infrastructure continue to grow and we move further toward open client-server architecture where integration of data is more important. This program was first to use two powerful organizational tools, IDEF and BPR, and apply them to a data communications infrastructure. This is the first step toward an architecture that now establishes the frontier in medical data communications infrastructure.

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